ERC Advanced Grant CRESUCHIRP + Brittany Region ARED CHIRPED – PhD Position starting October 2020

Title of Thesis: CHIRPED: Ultrasensitive detection of transient species by chirped pulse millimeter-wave spectroscopy – cold COMs and hot small molecules

Thesis subject: The ARED CHIRPED project is part of the ERC Advanced Grant programme CRESUCHIRP. Its main aim is to exploit the novel instruments constructed by the CRESUCHIRP project group (an international team consisting currently of 3 PhD students and 3 postdocs from the US, Australia, New Zealand, India, Algeria and France) in order to investigate the formation and destruction mechanisms of so-called complex organic molecules (COMs) in the extremely cold environments of dense interstellar clouds and star-forming regions (down to temperatures as low as 5 K), as well as to aid the detection of such species in much hotter environments such as the outflows of red giants and hot exoplanet atmospheres.

A major achievement of the Rennes Laboratory Astrophysics group has been to demonstrate that many reactions of neutral chemical species called radicals (atoms or molecules possessing one or more unpaired electrons) with other neutral molecules actually become faster as the temperature is lowered, contrary to expectation (Descartes prize, multiple articles in Science, Nature Chemistry, Phys. Rev. Letters etc). However, until now the precise identity of the products of such reactions has not been determined, for example even the simple reaction between the CN radical and ethene has two possible energy-releasing channels

\[ \text{CN} + \text{H}_2\text{C} = \text{CH}_2 \rightarrow \text{H}_2\text{C} = \text{CHCN} + \text{H} \quad (1a) \]

\[ \rightarrow \text{H}_2\text{C} = \text{CH} + \text{HCN} \quad (1b) \]

To date no measurement of the relative proportions of the products from the overall reaction has been made at temperatures below 100 K, or indeed for any other such reactions, despite the strong need for such information as input to astrochemical models. The main objective of the ERC CRESUCHIRP project is to develop a new method – the CPUF (Chirped Pulse in Uniform Flow) technique recently established by Ian Sims and his US collaborators Robert Field (MIT) and Arthur Suits (U Missouri) – into a tool capable of measuring such branching ratios. The principal scientific objective of the CHIRPED project will be to apply these new techniques to reactions involved in the formation and destruction of so-called Complex Organic Molecules or COMs, interstellar molecules containing 5 or more atoms. Studying the products of such reactions involves the detection of transient species or radicals such as CH$_3$O or CH$_3$OH from, for example, the reaction of CN with methanol, CH$_3$OH, a simple COM. A secondary objective will be to move the CPUF technique to a higher temperature regime, using a high enthalpy source coupled to a custom Laval nozzle to produce vibrationally hot species, with a cold rotational temperature, enabling their detection in the laboratory by mm-wave spectroscopy, and subsequently in collaboration with radio astronomers, their detection in hot astrophysical environments such as the outflows of red giants / late AGB stars and hot exoplanet atmospheres.

The PhD student would enjoy excellent interactions with the multinational CRESUCHIRP project team and would also benefit from an exceptional technical environment constructed within the framework of the CRESUCHIRP project, both in terms of dedicated and high-quality laboratory space as well as custom built high performance scientific instruments. The project will be undertaken within the vibrant context of the Rennes Laboratory Astrophysics group (https://ipr.univ-rennes1.fr/en/labastro) within the Molecular Physics Department of the Institute of Physics Rennes. The Rennes Laboratory Astrophysics group is internationally known for its experimental studies of elementary processes of interest for astrophysics, atmospheric science and combustion, and provides an excellent environment for PhD training.

The position is available starting in September-October 2020 for a period of 3 years. Candidates should possess a Masters degree (M2) in physics or (physical) chemistry. Experience in experimental research and especially the use of lasers, spectroscopy, vacuum techniques and high-speed electronics would be advantageous. Inquires and applications, including a detailed CV citing grades, an accompanying letter, and the names and contact details of three referees, should be addressed to Prof. Ian Sims (ian.sims@univ-rennes1.fr). Further details of the project can be seen on the CRESUCHIRP website: https://cresuchirp.wordpress.com

Keywords: Chirped Pulse Fourier Transform Microwave Spectroscopy (CPFTMW), CRESU, Low Temperature Reaction Kinetics, Product Branching Ratios, Elementary Reactions, Molecular Astrophysics, Experimental Astrochemistry, Chemical Physics, COMs, Rotational Spectroscopy, Gas-Phase Physical Chemistry